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MAPPING CHANGES IN SPATIAL EXTENT IRRIGATED AND RAINFED CROPPED AREAS AT THE BACKDROP OF GREEN REVOLUTION

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ABSTRACT

Green Revolution was at its core a sort of technological response to the global food shortages that erupted out of the Second World War and claimed large chunks of population. It India it has its root in the food crisis which engulfed the nation in the very beginning of its journey as an independent nation. Using Normalised Difference Vegetation Index images of Advanced Very High Resolution Radiometer satellite dataset this study tends to map the changes in spatial extent of irrigated and rainfed cropped areas after the onset of green revolution. The result of the study shows an eastward extension of the irrigated agriculture as well as newer areas in central India coming under the ambit of irrigated agriculture.

KEYWORDS: Irrigated and Rainfed Agriculture, AVHHR, NDVI

INTRODUCTION

Green revolution has been the subject of so intense debate that an another text about it hardly seems necessary. However the revolution of the 60's which enabled Least Developed Countries (LDC's) countries like India to overcome chronic hunger, food crisis and huge food imports through a significant rise in domestic foodgrain output continues to evoke considerable interest among researchers and policy makers regarding the nature of its impact, particularly its implications for growth, equity and sustainability (Ninan & Chandrashekar, 1993). This interest received a wave of new thrust due to the crisis in 'green revolution' regions of the country. Even several decades after the launch of the green revolution, the Indian agriculture, for the most part remains subsistence agriculture. It revolutionized farming practices in wide extents in both tropical and subtropical regions with major emphasis on three crops namely rice, wheat and maize that were regarded as the principal food crops within these regions. Though similar to other technologies it also had its undesired consequences, but nevertheless it proved to be a miracle for millions with a hungry appetite and begging bowl. The green revolution severed the food crisis with remarkable and an unprecedented speed which in turn led to a considerable decrease in poverty reduction and broadening the spectrum of economic progress in various regions.

Green revolution in India has its root in the food crisis which further severed after the crisis in 1947 resulting in a series of problems to the agricultural sector. Even during good harvest years the food imports remained high and rocketed after a series of droughts in the 60's forcing India to adopt the green revolution technology (Rena, 2004). The packaged technology embedded modern farming technology, introduction of high-yielding varieties of seeds, increased use of fertilizers, development and expansion of irrigation systems, and extension of credit and educational services to the farmers (Deshpande, 1986, Singh, 2001). India was among the first developing countries to adopt farming strategies under the green revolution in the mid-1960. The crisis situation of the 60's prompted the government to step in and advise a new

policy – a new agricultural strategy for increasing the agricultural production within the shortest possible time and for minimizing fluctuations in agricultural production on account of unfavourable weather conditions which came to be known as the ‘green revolution’ (Rena, 2004).

In the context of the growth achieved by the green revolution certain issues have cropped up with time which has been incurring an important dimension to the Indian agriculture. Regardless of the positive trends, the green revolution lost stem as agricultural growth declined severely in the mid-1990’s. The fundamental transformation of the rural economy as envisioned by the early planners did not occur. Compared to the earlier period of agricultural modernization – the so-called ‘green revolution’ – the current phase does not allow agricultural innovation policies to be guided by national development priorities. The public institutions which shaped the green revolution policies, both at the level of national governments and in international agricultural research organizations, are shrinking in importance and are in the process of being replaced by unregulated, transitional market forces (Nanda, 2000).

However the Indian agricultural sector has answered to the requirements that it must play to service the development of the rest of the economy by performing the necessary role of providing food, basic agro-industrial raw materials and wage goods, labour and financial resources for the development of the non-agricultural economy – while the agrarian society provides a national market for its consumer goods (Harriss-White, 2008). Since the onset of the green revolution, the rainfed areas had to bear the brunt of the backlash effects of the green revolution ushering changes in the spatial extent of rainfed and irrigated agriculture, setting in regional variations. Thus it is imperative to draw the variations in the actual extent of the irrigated and rainfed cropland areas with the advancement of the irrigated agriculture.

STUDY AREA

Spreading over 3.28 million sq. km area, India lies completely in the northern hemisphere with tropic of cancer passing through its middle. It extends between latitudes 8° 4' and 37° 6' north, longitudes 68° 7' and 97° 25' east with a total east-west expansion of 2933 km and a north-south expansion of 3214 km. As a distinct geographical entity the region is bounded by lofty ranges in the north and Arabian Sea and Bay of Bengal in west and east respectively. Containing from the oldest Archean rocks to the newest fold mountains, the region encompasses the largest plain region of the world. The entire area falls under monsoon climatic conditions which are marked by seasonal reversal of winds twice a year. Majority of the rainfall is concentrated within the monsoon months with three prominent regions of high rainfall.

DATABASE

The study is based primarily on Normalized Difference Vegetation Index (NDVI) images of Advanced Very High Resolution Radiometer satellite dataset (Tucker, 2004). For this the present study covers a time span of 25 years extending from 1982 to 2007. Using AVHRR the distribution of single and double cropland areas will be mapped and analysed for 1982, 1985, 1990, 1995, 2000, 2003 and 2007[1].

The Advanced Very High Resolution Radiometer (AVHRR) acquired data in 5 spectral bands; one visible, one near infrared and three thermal bands, all with 1024 quantizing levels. The thermal bands are not used in the GIMMS NDVI data. The AVHRR produces at 1.1 and 4 km spatial resolution. The 4-km product or global area coverage (GAC)

[1] Though the impact of Green revolution started from 1970’s onwards, the period has not been included in the study due to unavailability of satellite based imagery for the concerned period as the official archiving began only in late 1970’s.

product is derived from the 1-km product by onboard sampling. The 4-km product is available globally from July 1981 until the present. The 1-km record is not continuous. Its availability depends upon prior arrangements made by NOAA, or on the proximity of a local receiving station that can capture the data directly from the satellite.

The NOAA AVHRR satellite series 7, 9, 11, 14 and 16 used for this NDVI record flew in sun-synchronous polar orbits with a nominal 1:30 or 2:30 PM local daytime overpass time at launch. NOAA 7 data span the years 1981 -1985, NOAA 9, 1986-1989, NOAA 11, 1989-1995, NOAA 14, 1995-2000, and NOAA-16 from 2000 to 2004 (and continues through the present). Global NDVI[2] was generated to provide inputs for computing the time series of biophysical parameters contained in the International Satellite Land Surface Climatology Project (ISLSCP) Initiative II collection.

METHODOLOGY

The present study spanning over 25 years utilizes a host of remote sensing techniques to delineate the irrigated and rainfed cropland areas. The basic process involves the composition of mega-file data-cube, segmenting the entire region into characteristic regions that are easier to analyse, performing an unsupervised classification on each segment, identification of spectral classes, calculating actual area using Sub-Pixel Area.

First of all, NDVI product for two different time periods 1982, 1985, 1990, 1995, 2000, 2002 and 2007 was collated. The 15 day synthesized images are compiled by merging segments (data strips) acquired over 15 days. For each year 24 images (15 day composite) were downloaded and stacked to form a mega-file data cube. The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses visible and near-infrared bands of the electromagnetic spectrum to assess whether the target being observed contains live green vegetation or not.

$$\text{NDVI} = \frac{\text{Channel 2} - \text{Channel 1}}{\text{Channel 2} + \text{Channel 1}}$$

The principle behind NDVI is that *channel 1* is the red-light region of the electromagnetic spectrum where chlorophyll causes considerable absorption of incoming sunlight, whereas *channel 2* is the near-infrared region of the spectrum where a plant's spongy mesophyll leaf structure creates considerable reflectance. As a result, vigorously growing healthy vegetation has low red-light reflectance and high near-infrared reflectance and, hence, high NDVI values (USGS, 1987). The calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.

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[2] Green leaves have a higher reflectance in the AVHRR near infrared band (band 2) than in the visible band (band 1), because of differences in leaf chlorophyll absorption between the two bands. Chlorophyll absorbs strongly in the red region, spanned by AVHRR band 1. Thus, the difference in vegetation reflectance between the near infrared and visible bands increases with green leaf vegetation density, hence chlorophyll concentration. The ratio of the difference between band 2 and band 1 and their sum, hence the NDVI, is an index that ranges between -1and +1; the observed range is usually smaller: Non-vegetated materials generally have a much lower NDVI (around 0) than dense vegetation (>0.7), since their near infrared and visible reflectances are more nearly equal.

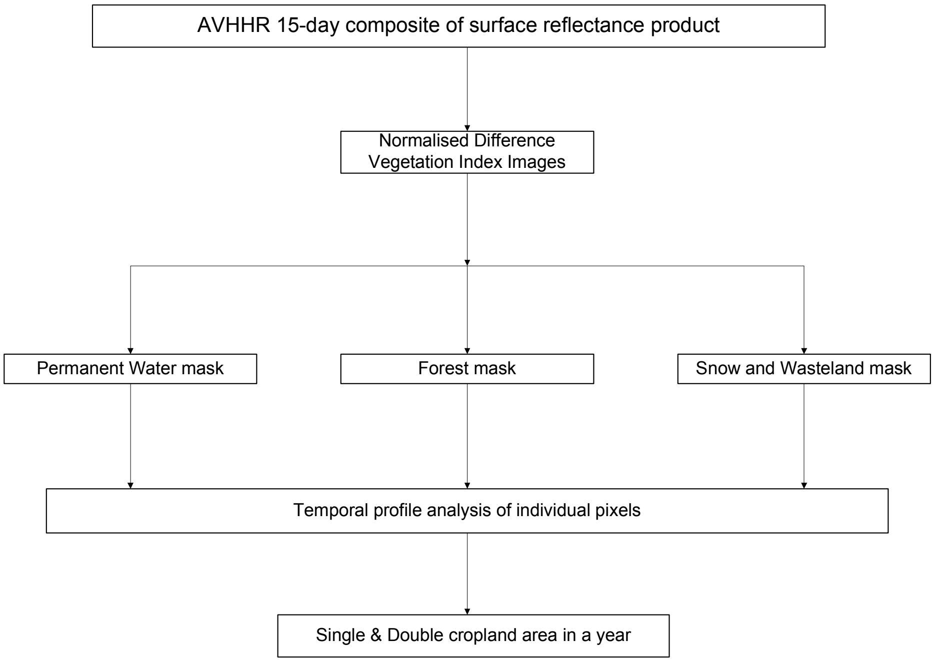

Figure 1: Application of Phenology Based Algorithm for Identifying and Mapping Rainfed and Irrigated Croplands (Using the AVHHR Dataset)[3]

The entire dataset was analyzed for the behaviour of forests, water bodies, snow lands and wastelands so that the dates during which these areas have a contrasting difference in reflectance from the rest of the agricultural area. So using selected images i.e. when the difference in reflectance was highest, a k-means unsupervised classification was applied and the spectral identification was carried out with the help of spectral profiles and Forest Atlas of FSI (Forest Survey of India). The k-means algorithm uses Euclidean distance to describe similarity among pixels characterized by measurements of a single variable at multiple time points. The non-agricultural areas were masked on the mega-file data cube to obtain the remaining agricultural area. Again, k-means unsupervised classification was applied using the mask of agricultural area for the entire region. A maximum of 300 classes at 6 iterations were attempted. For every class, 10 Google Earth very high resolution "zoom-in-view" sample locations were investigated. For each investigated point a class name was given based on image interpretation techniques such as shape, size, texture, location and proximity to water sources.

RESULTS AND DISCUSSIONS

Though the green revolution was introduced in 1966-67 and its impact on agriculture started to appear by mid-1970's, the present study entails the changes since early 1980's due to the unavailability of remote sensing datasets prior to 1980 as the official archiving began only since the early 1980's. By the period of 1982 the green revolution has spread to almost entire Punjab and Haryana states and covered major portions of Uttar Pradesh and had started stretching further eastwards into Bihar in the Indo-Gangetic plains. Apart from these three states all other states except Mizoram had double cropped areas in varying degrees. The least area under double cropland were in the states of Kerela, Nagaland and Tripura.

[3] We assume that the single cropland areas represent s the rainfed cropland areas.

In Punjab certain regions falling within Hoshiarpur, S.B.S Nagar, Rupnagar, S.A.S Nagar, Kapurthala, Tarn Taran and Patiala still practiced rainfed agriculture. Except Tarn Taran and Kapurthala rest all the districts lied in the border region with Himachal Pradesh. Out of these Rupnagar had the maximum area under rainfed cropland. In Haryana green revolution had a far better coverage with only three districts namely Yamuna Nagar, Ambala and Panchkula having fewer regions under rainfed agriculture. Out of these Ambala had the highest area under rainfed cropland. Within Uttar Pradesh, the western region has benefitted more through the green revolution than the eastern region with majority of districts with rainfed cropland lying in the eastern region. In the western regions districts namely Saharnpur, Muzaffarnagar, Merrut, Bijnor, Moradabad, Bareilly, Pilibhit and Rampur has little areas under rainfed agriculture. On the other hand districts in the eastern region had significant areas under rainfed croplands. These included Kheri, Sitapur, Bahraich, Shrawasti, Gonda, Balrampur, Bara Banki, Faizabad, Sid, Kus, Maharajganj, Deoria and Basti.

Moving further eastwards in the Indo-Gangetic plains, only a few districts in Bihar state has employed the technological know-how under the green revolution. A very striking feature of the spread of green revolution technology towards these regions is that rather than the spread being distributive in nature, it was mainly concentrated in regions having border with Uttar Pradesh signifying an inductive spread of the technology from one region to the surrounding region. These regions mainly included Bhabua, Rohtas, Buxar and Bhojpur districts. Apart from these, some other districts also had double cropland areas which included Patna, Nalanda, Jehanabad, Arwal, Begusarai, Khagaria, Madhepura, Gaya and Aurangabad. Thus only four states namely Punjab, Haynana, Uttar Pradesh and Bihar formed the largest area under the green revolution technology. Apart from these regions other double cropped regions were in Assam, Jammu and Kashmir, Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu.

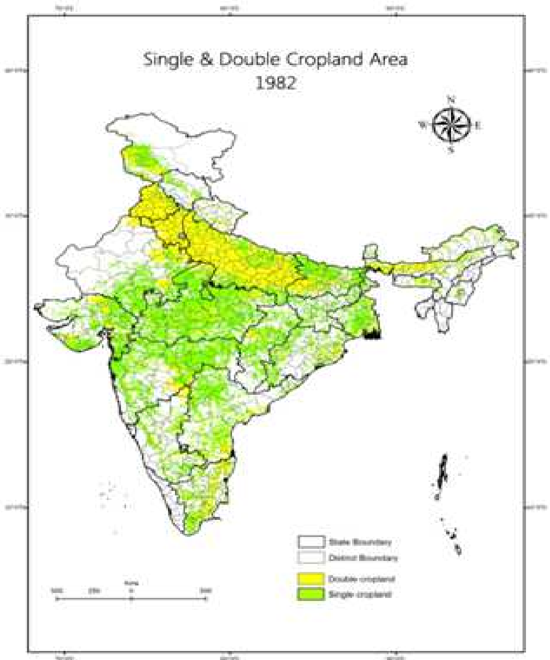

Figure 2: Single & Double Cropland Areas, 1982

Looking at the distribution of rainfed cropland areas, the majority of such cropland was located in the central India with Madhya Pradesh and Maharashtra having the major chunk. Other significant areas under rainfed cropland were

found in Rajasthan, Gujarat and Andhra Pradesh. The regions under present Chhattisgarh and Jharkhand states too had widespread rainfed cropland areas. In Madhya Pradesh except the bordering districts all other districts had very high percentage of rainfed cropland areas. Most of the districts in the central region also had patches of double cropped areas. The major rainfed districts included Guna, Vidisha, Ashoknagar, Shivpuri, Sheopur, Tiakmgarh, Chatarpur, Sagar, Damoh, Panna, Satna, Katni, Rewa, Narshimapur, Raisen, Hoshangabad, Narshimapur, Sehore, Dewas, Indore, Dhar and Ujjain. Districts with lower rainfed cropland included Sidhi, Sahdol, Anuppur, Dindori, Mandla, Balaghat and East Nimar. In Maharashtra, the rainfed cropland were mainly concentrated in the north-western districts. These included mainly the regions such as Gondiya, Bhandara, Wardha, Nagpur, Amravati, Akola, Buldana, Washim, Yavatmal, Chandrapur, Nanded and Hingoli. In the north-western region districts like Jalgaon, Dhule, Nashik and Thane were the main areas of dryland agriculture. In the southern region Kolha, Satara, Sangli and Pune were the major areas of dryland agriculture. However districts like Solapur, Osmanabad, Bid, Jalna and Ahmednagar in the south accounted for the regions having the least areas under rainfed croplands.

The western part of India comprising Rajasthan and Gujarat too have large areas under rainfed agriculture. Rajasthan is in fact the driest sate of India. Aridity in this region decreases from west to east. In the western part Bikaner and Jaisalmer were devoid of any such type of significant agriculture. Running from north to south districts like Churu, Nagaur, Jodhpur, Pali, Barmer, Jalor, Sirohi, Tonk and Jaipur had lesser areas under rainfed croplands. The majority of rainfed agriculture in Rajasthan was concentrated in the southern districts of Bhilwara, Rajsamand, Udaipur, Chittaurgarh, Pratapgarh, Banswara and Dungurpur. However five districts namely Hanumangarh, Bundi, Kota, Sikar, Jaipur, and Alwar had significant double cropped areas. In Gujarat the rainfed areas were mainly located in the extreme south and north-western districts. In the southern part significant dryland croplands were found in Junagadh, Amreli, Valsad, Navsari, Tapi, Surat, Baruch and Narmada. In the north-western region districts with major cropland areas were Dohad, Panch Mahals, Kheda, Sabar Kantha and Mehesana.

In South India Andhra Pradesh also has large areas under rainfed croplands which were concentrated mainly in the northern part and south-eastern part. The districts with higher rainfed areas in the northern region were mainly Adilabad, Nizamabad, Karimnagar, Medak, Warangal and Rangareddy. As opposite to this the major rainfed districts in the south-eastern part were Prakasam, Nellor, Y.S.R and Guntur. Apart from this, regions with lower rainfed cropland were East Godavari, West Godavari and Krishna in the north and Anantpur and Kurnool in the south. The double cropped areas in the region developed primarily in the coastal areas in the districts of Nellor, Prakasam, Guntur, Krishna, East Godavari and West Godavari. In the eastern region West Bengal has extensive areas under rainfed agriculture with majority of these distributed over the southern districts South Twenty Four Parganas, Purba Medinipur, North Twenty Four Parganas, Paschim Medinipur, Barddhaman, Birbhum and Murshidabad. Out of all the districts, Puruliya has the least area under the rainfed croplands. On the other hand two districts namely Jalpaiguri and Koch Bihar. In the north-eastern region of the country the rainfed cropland existed only in smaller patches. The largest state in north-eastern region i.e. Assam had substantial areas under double crop with fewer areas under rainfed cropland mainly in the eastern part of the state. Apart from this the central regions in Meghalaya had some area under rainfed croplands. The two southern most states namely Tripura and Mizoram were devoid of any significant cropland areas.

The year 1985 not being a good rainfall year did not register advancement in the total cropped area. It even experienced shrinkages in area under cultivation within several regions. In the power house of green revolution i.e.

Punjab and Haryana did not register any significant change in the area under cultivation or the type of cultivation. Moving towards the east Uttar Pradesh saw a little increase in the single crop area in the north central districts. In Bihar surprisingly the area under double crop increased. This jump was attributed mainly to rise of double cropped areas in the north-western part of the state. In the western region Rajasthan had some double cropped areas in the northern and western region. Other significant double cropped areas were in Assam and the coastal areas of Andhra Pradesh and Tamil Nadu.

In the case of rainfed areas one of the most significant aspect that appeared over the entire region was a rise in the concentration of such croplands at the regional level in Maharashtra and Madhya Pradesh. In Maharashtra the major districts under the rainfed croplands were Nagpur. Wardha, Amravati, Akola, Buldana, Jalgaon, Washim, Hingolil,Yavatmal, Thane and Nanded. Districts with relatively lesser area under rainfed cropland were Solapur, Satara, Sanli, Pune and Ahmadnagar. In Madhya Pradesh the major concentration of rainfed croplands were in the districts of Sheopur, Shivpuri, Tikamgarh, Chhatrarpur in the north; Rajgarh, Shajapur, Ujjain, Indore, Dewas, West Nimar, East Nimar, Burhanpur and Harda in the eastern and southern region. Other regions of increased concentration of rainfed croplands were observed in the northern and north-eastern parts. Further to the east in West Bengal the major areas of rainfed cropland were in the northwest and north-eastern parts.

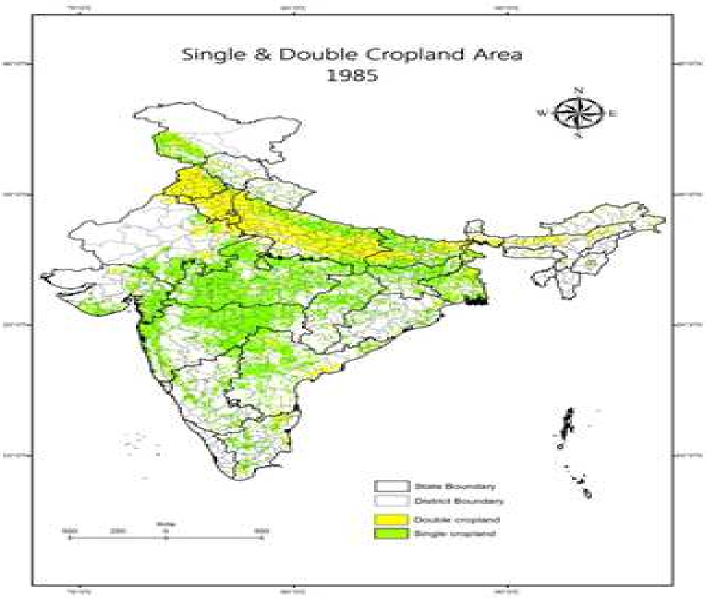

Figure 3: Single & Double Cropland Areas, 1985

By 1990 the expansion of green revolution technologies to the central and eastern regions of the Indo-Gangetic plains had more or less completed. The expansion mainly included parts of central and northern Uttar Pradesh and majority of parts of Bihar. Such considerable expansion was also evidenced in large parts of West Bengal and two continuous stretches in Madhya Pradesh. In Punjab certain regions falling within Hoshiarpur, S.B.S Nagar, Rupnagar, S.A.S Nagar, Kapurthala, Tarn Taran and Patiala which earlier practiced rainfed agriculture, now had access to irrigation and could harvest double crops. Except Tarn Taran and Kapurthala rest all the districts lied in the border region with Himachal Pradesh. In Haryana three districts namely Yamuna Nagar, Ambala and Panchkula earlier having regions under rainfed agriculture, had been successful now in converting those regions into irrigated agriculture. Thus by the time of 1990 both Haryana and Punjab were completely under the umbrella of green revolution. In Uttar Pradesh except four of the southern

districts namely Banda, Chitrakoot, Allahabad, Mirzapur and Sonbhadra, the entire region was under irrigated agriculture depicting remarkable progress in the dissemination of green revolution in the central and northern parts of the state. In the western regions districts namely Saharnpur, Muzaffarnagar, Merrut, Bijor, Moradabad, Bareilly, Pilibhit and Rampur which earlier had little areas under rainfed agriculture, were now almost under irrigated agriculture. The most significant change occurred in the districts of the eastern region that earlier had significant areas under rainfed croplands, but now were completely a double cropland region. These included Kheri, Sitapur, Bahraich, Shrawasti, Gonda, Balrampur, Bara Banki, Faizabad, Sid, Kus, Maharajganj, Deoria and Basti. Thus the eastern region caught up with the western region which has earlier progressed at snail's pace.

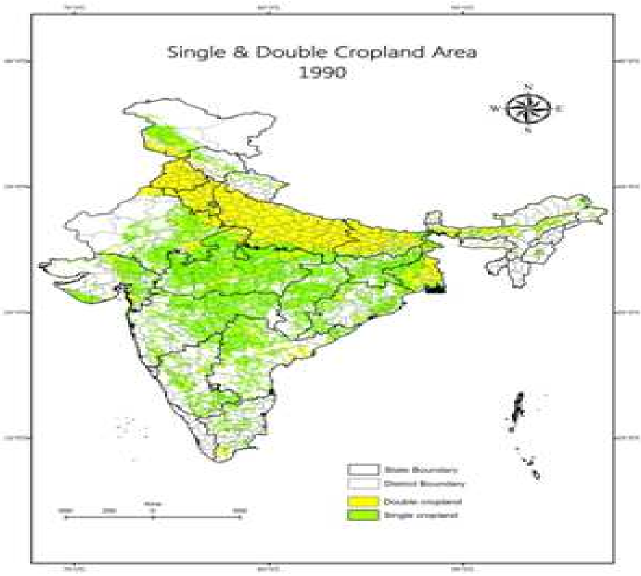

Figure 4: Single & Double Cropland Areas, 1990

Moving further eastwards in the Indo-Gangetic plains Bihar made the most spectacular progress in the application of green revolution technologies during the last decade. Except three districts all other districts had majority of their areas under irrigated croplands. Thus only four states namely Punjab, Haynana, Uttar Pradesh and Bihar formed the largest area under the green revolution technology.

Within the rainfed cropland regions Madhya Pradesh still has the most extensive areas falling under dryland farming. But a major change within the region was the formation of two continuous stretches of double cropland areas – one in the central and one in the northern region. The rainfed croplands occupied almost the entire region except some limited presence in the south-eastern and south-western districts. In Maharashtra the presence of rainfed croplands was extensively in the western part of the state. The districts in its central part continued to remain too dry. In Andhra Pradesh the majority of rainfed croplands were in the northern districts. In Jharkhand, except Purbi Singhbhum in the south and a few districts in the north the entire state was under rainfed agriculture. These included Ranchi, Lohardaga, Palamu, Hazaribag, Dhanbad, Sahibganj. In the north-eastern states of India the status quo was maintained and there was no as such any significant change in the distribution of either types of crops. In the western part of India, Rajasthan and Gujarat too did not cast any major alteration in the coverage of rainfed cropland areas.

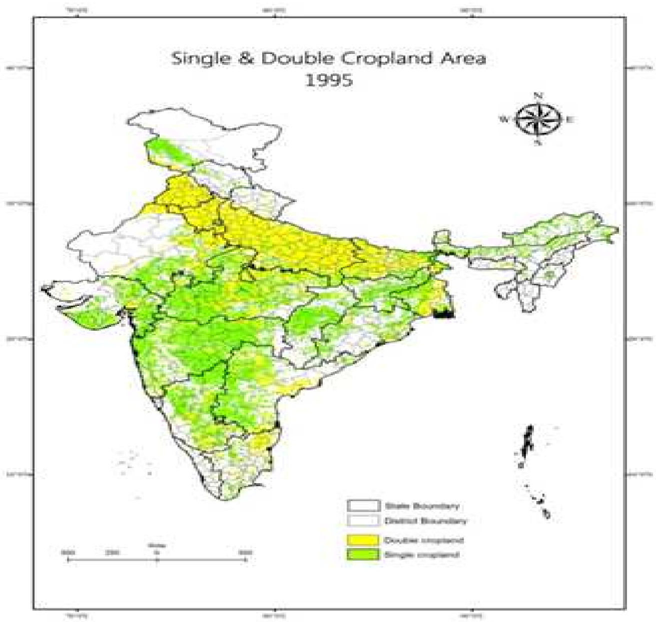

Figure 5: Single & Double Cropland Areas, 1995

Between 1990 to 1995 there was no major change in the coverage of double cropland areas except for some parts in Uttar Pradesh. Four of the southern districts in Uttar Pradesh namely Banda, Chitrakoot, Allahabad, Mirzapur and Sonbhadra which earlier had large areas under rainfed croplands were now under double croplands to a major extent. However in Bihar, the conditions remained quite similar to the previous periods and there was no further extension of irrigated agricultural lands in the region. Districts mainly Jamui, Kishanganj, Banka and Araria still had a sizable area under rainfed croplands. Another new region of double cropland came up in the northern part of Rajasthan covering parts of Sikar and Jaipur districts. Double cropland also gained prominence in the coastal areas of Andhra Pradesh and Tamil Nadu.

The distribution of rainfed cropland involved a large scale increase in the southern state of Karnataka and it appeared one of the prominent regions of dryland agriculture in India. The districts with higher area under rainfed cropland were Gulbarga, Bidar, Belgaum, Bagalkot, Dhawad, Haveri, Bellary, Tumkur, Hassan and Chikkabakkapura. Other districts mainly Bangalore Rural, Ramanagara, Chitradurga, Bijapur and Koppal had lesser area under rainfed agriculture. Another significant growth of rainfed cropland area was in the north-eastern state of Arunchal Pradesh. The major districts involving the change were Tawang, West Kameng, East Kameng, Kurung Valley, Upper Subansiri, West Siang, Upper Siang, Anjaw, Changlang and Dibang Valley. However the rise of area under cropland was not exceptionally high due to rough terrain. In other parts of the country mainly the dry western region there was no change in cropland areas on a high degree. Thus the major changes during the span of five years mainly took place in the southern and north-eastern part of the country.

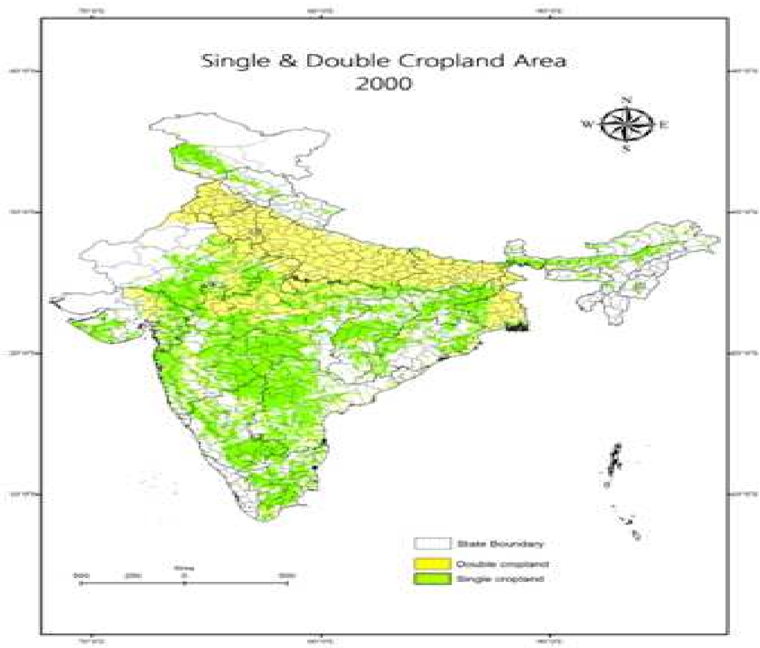

Figure 6: Single & Double Cropland Areas, 2000

By the end of the century irrigated agriculture had moved out of the Indo-Gangetic plains and covered new areas in western Madhya Pradesh. District-wise it occupied parts of Indore, Ujjain, Dewas, Shajpur, Sehore, Bhopal, Vidisha and Sagar. A long narrow east-west extending stretch of double cropland in the central part included parts of Dewas, Harda, East Nimar, Raisen, Narsimhapur and Jabalpur districts. Another stretch of double croplands in the northern part extends over Rewa, Satna, Panna and Damoh districts. Except some of the districts in the south-eastern and eastern part rest of the region had extensive areas under rainfed agriculture. In West Bengal the double cropland areas developed prominently in the eastern, southern and northern districts mainly including South Twenty Four Parganas, North Twenty Four Parganas, Haora, Hugli, Purban Medinipur, Nadia, Barddhaman, Birbhum, Murshidabad, Maldah, Dakshin Dinajpur and Uttar Dinajpur.

In Maharashtra the rainfed cropland areas covered the entire central and eastern region and a narrow stretch in the western part. Regions which were devoid of rainfed agriculture due to highly unsuitable climatic conditions included regions of districts namely Dhule, Nashik, Ahmadnagar, Pune, Satara, Solapur and Sangli. In Karnataka similar regions occurred in districts mainly Bijapur, Bagalkot, Koppal, Chitradurga and Gadag. In Andhra Pradesh such regions occurred in the northern coastal districts.

Thus, it became clear that between 1982 to 2000, the double cropped areas completely covered the entire Indo-Gangetic plains and also a significant part in Madhya Pradesh and West Bengal. On the other hand Madhya Pradeh, Maharashtra, Karnataka, Andhra Pradesh, Rajasthan, Chhattisgarh and Jharkhand formed the core of rainfed agriculture in India.

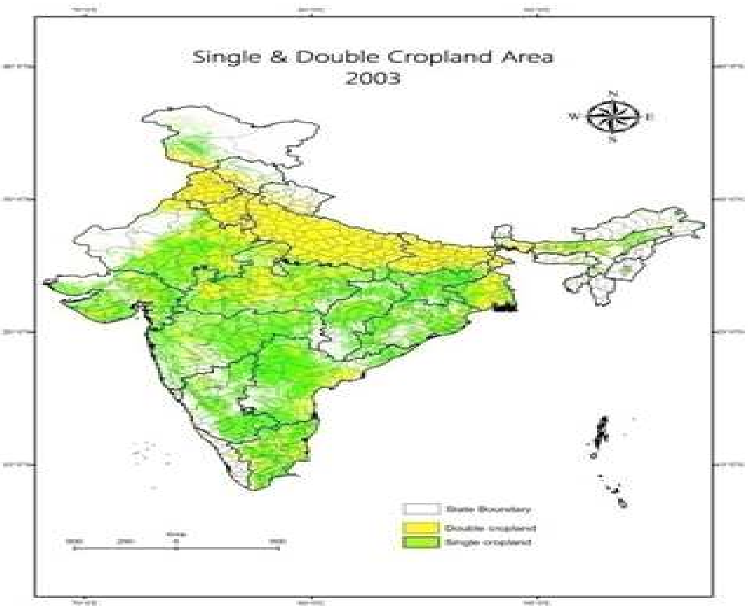

Figure 7: Single & Double Cropland Areas, 2003

Within the next three years, growth in area under double cropland was reported mainly from Gujarat and the southern Indian states. In Gujarat significant double cropland areas came up in Junagarh, Amreli and Rajkot districts in south-west. In the north, central and southern parts districts mainly Anand, Kheda, Banas Kantha and Mahesana. Surat. In Maharashtra which is one of the largest rainfed cropland states, double cropland areas came up in several patches in districts namely Nashik, Ahmadnagar, Pune, Satara, Kolhapur, Nanded, Jalgaon and Nagpur. In Karnataka, the growth was relatively slower and only three districts namely Belgaum, Davanagere and Bellary has some areas under double crop. Out of the three Belgaum had the highest area under double cropland. In Andhra Pradesh districts namely Warangal, East Godavari, West Godavari, Guntur, Prakasham, Nellor and Chittoor had significant areas under double cropland. Out of all the southern states Tamil Nadu had the highest area under double cropland which were mainly spread over Thiruvallur, Kancheepuram, Tiruvannamalai, Vellor, Erode, Salem, Cuddalore, Nagapattinam, Thiruvalur, Thanjavur, Tirunelveli, Kanniyakumari, Theni, Dindigul and Coimbatore districts. In Kerala only one district namely Pallakad had significant area under double cropland.

Coming to the distribution of rainfed cropland areas, there was considerable rise in the area under rainfed cropland mainly in the states of Jharkhand, Odisha, Andhra Pradesh, Chhattisgarh, Gujarat and Karnataka. The highest rise in area under rainfed cropland was in Jharkhand and Odisha. In Jharkhand steep rise in rainfed areas was seen in Garhwa, Palamu, Gumla, Simdega, Saraikela and Chatra. In Odisha the major growth were in Kendujhar, Sundargarh, Nuapada, Balangir, Subarnapur, Baudh, Angul, Dhenkanal, Puri, Ganjam and Gajapati. In Andhra Pradesh rapid rise in rainfed cropland area was visible in Srikakulam, Vizianagaram and Vishakhapatnam. Apart from this in the western part in Gujarat, rainfed areas came up prominently in Amreli, Bhavnagar, Rajkot and Surendranagar.

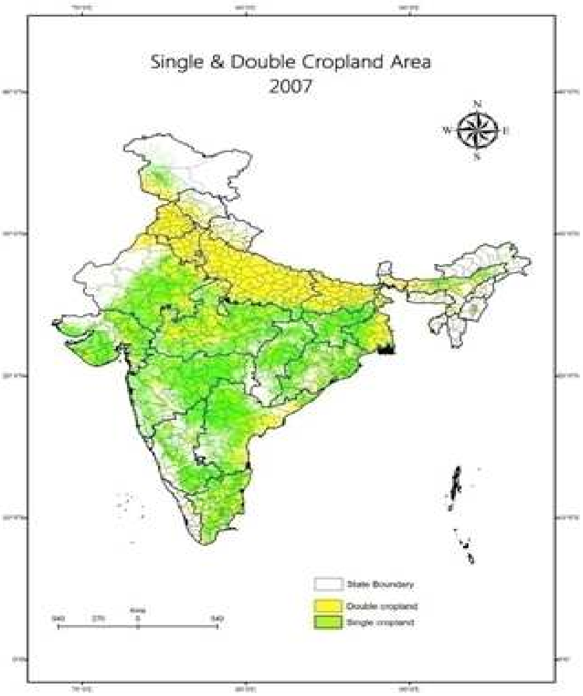

Figure 8: Single & Double Cropland Areas, 2007

By 2007 there was not any such significant change in the distribution of either double cropped or rainfed areas. In fact there was some decrease in the extent of rainfed cropland areas. In the double cropland category some increase was seen in the districts of Andhra Pradesh namely Khammam, Nalgonda, Vishakatpatnam and East Godavari. Some increase in the double cropland was also noticed in the Thiruvallur and Kancheepuram districts. In Karnataka, the double cropland areas in three districts namely Belgaum, Davanagere and Bellary increased further. Out of the three Bellary now had the highest area under double cropland. Thus by the end of the century and further till 2007 irrigated agriculture had moved out of the Indo-Gangetic plains and covered new areas in western Madhya Pradesh.

CONCLUSIONS

Thus the changes in spatial extent of double cropland areas since 1982 shows an exclusive pattern of eastward progression over the years. On the other hand the areas under single cropland appeared to be spatially stable without much drastic changes. By 1982 the double cropland areas covered major parts of Punjab, Haryana and western U.P which extended further till central Bihar by 1990. Till 1995 almost entire Bihar was under the double cropland while the extension continued with new areas of double cropland emerging in central Madhya Pradesh. By 2000, almost the entire Indo-Gangetic Basin was under double cropland. So, it became clear that between 1982 and 2007, the double cropped areas completely covered the entire Indo-Gangetic plains and also a significant part in Madhya Pradesh and West Bengal. However the double cropland areas remained within 80-100 cm rainfall zone. Though the sub-humid regions extending over eastern India receives higher rainfall, the rough topography restricts the extension of double cropland areas into these regions. On the other hand Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Rajasthan, Chhattisgarh and Jharkhand formed the core of rainfed agriculture in India.

Thus it is meaty to note that how the interplay of the dynamics of rainfed agriculture and green revolution - a symbol of irrigated agriculture, has shaped India’s agriculture from the early decades of independence to the present times passing though three different stages of the early acute crisis, boom through green revolution and the latest of depression again. Since the very extension of irrigated agriculture is bound with the development of perennial irrigation facilities, the irrigated agriculture has hardly moved to any significant level beyond the Indo-Gangetic plains. But even with half the area of rainfed agriculture, the irrigated agriculture has been riding the crest with rainfed areas bearing the brunt.

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